Catena 113 (2014) 86–94

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Soil richness and endemism across an environmental transition zone in Wisconsin, USA

James G. Bockheim [a,*], Sarah A. Schliemann [b]

[a] Department of Soil Science, University of Wisconsin, Madison, WI 53706-1299, United States
[b] Department of Earth and Atmospheric Science, Metropolitan State University, Denver, CO 80217-3362, United States

ARTICLE INFO

Article history:
Received 26 April 2013
Received in revised form 23 September 2013
Accepted 26 September 2013

Keywords:
Pedodiversity
Ecotone
Soil classification
Rare and unique soils

ABSTRACT

Soil richness was examined across the Wisconsin ecological tension zone, which constitutes a transition between the central hardwood forest and prairie biomes to the south and the northern mixed hardwood and conifer forest biome to the north. There were greater numbers (normalized by county area) of soil orders, suborders, and great groups in counties within the transition zone than in those outside the zone. A zone of soils containing glossic horizons extends 75 km to the north of the Wisconsin transition zone separates Alfisols (dominantly Hapludalfs) and Mollisols in the south from Spodosols and Glossudalfs in the north; this zone may represent the mid-Holocene position of the tension zone. Soil endemism is a concept whereby soils are restricted to a limited geographic area based on a unique set of soil-forming factors. In this study, endemic soils were identified on the basis of having a centralized distribution, lacking competing soil series, and being unique to Wisconsin and adjoining states. Although the transition zone contains 13% of the state's area, it has 40% of the endemic soils. Endemic soils in Wisconsin occur in 7 orders, 14 suborders, 29 great groups, 83 subgroups, and 138 families; they include 159 soil series that cover 1.44 million ha (19% of state land area). The predominant soil properties related to soil endemism include (i) the presence of a glossic horizon (34% of endemic soils), (ii) aquic conditions or oxyaquic subgroups (28%), and (iii) bisequal profiles (20%). There are 102 vascular plant species endemic to Wisconsin, the distribution of which appears to be related more to the landform than to soil taxa.

1. Introduction

The current interest in pedodiversity, or soil richness, is predicated on an interest in spatial variability for soil mapping and a linkage with biodiversity (Guo et al., 2003; Ibáñez and Bockheim, 2013; Ibáñez et al., 1995; McBratney, 1992). The concept of soil endemism refers to soils that are restricted to a particular geographic area based on a unique combination of soil-forming factors (Bockheim, 2005). This concept is gaining attention in the literature as a means of identifying rare and endangered soils (Bockheim and Haus, 2013). The diversity of plants and animals has received considerably more attention in the biogeography and ecology literature than the concepts of pedodiversity and soil endemism (Ibáñez and Bockheim, 2013).

The environmental tension zone in Wisconsin, USA constitutes a transition between the central hardwood forest and prairie biomes to the south and the northern mixed hardwood and conifer forest biome to the north (Fig. 1). The Wisconsin transition zone contains an average of 61 vascular plant species per county at their southern or northern range limits, whereas the mean numbers of species for the areas north and south of the transition zone are 26 and 28, respectively (Curtis, 1959). The Wisconsin tension zone is also a transitional zone for insects, birds, and other animals (Beimborn, 1970). The transition zone follows the current mean July air temperature isotherm of 21 °C (Fig. 2). Based on trajectory analysis of air masses, the Wisconsin transition zone also represents the mean winter position of the Arctic Frontal Zone (Bryson, 1966). The transition zone can be followed westward into Minnesota (Wheeler et al., 1992) and eastward across Lake Michigan into Michigan (Schaetzl et al., 2005). According to fossil pollen studies, the Wisconsin transition zone has shifted northward or southward in response to late- and post-glacial climate changes (Webb and Bryson, 1972). A variety of periglacial phenomena have been observed along the southern edge of the current transition zone (Fig. 1).

The Wisconsin transition zone roughly follows the separation between the mesic (≥8 °C) and frigid (<8 °C) soil temperature regimes (Fig. 1). Soils north of the transition zone are dominantly Spodosols under mixed coniferous and broad-leaved forest, and those to the south are primarily Alfisols under broad-leaved forest and Mollisols under native prairie (Hole, 1976).

The objectives of this study are to trace soil richness across the environmental transition zone, to identify endemic soils in Wisconsin, and to examine the relation between plant endemism and soil endemism in the state. Three hypotheses will be tested: (i) pedodiversity, or soil richness, will be greater within than without the tension zone; (ii) the

* Corresponding author. Tel.: +1 608 263 5903; fax: +1 608 265 2595.
E-mail address: bockheim@wisc.edu (J.G. Bockheim).

0341-8162/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.catena.2013.09.011

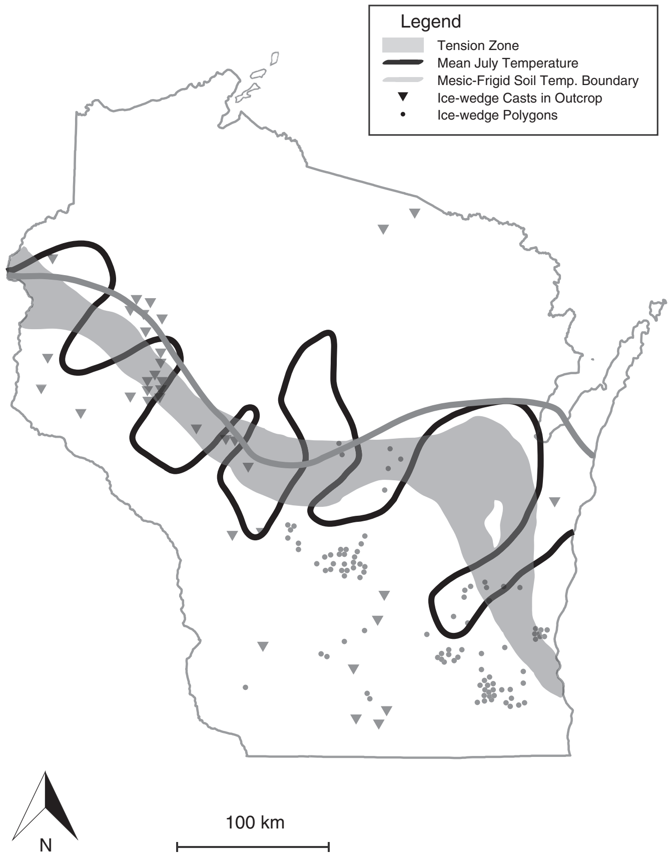

Fig. 1. Environmental tension zone in Wisconsin (after Curtis, 1959), mean July isotherm of 21 °C, distribution of periglacial features in Wisconsin (Clayton et al., 2001), and location of frigid–mesic mean annual soil temperature boundary (Schaetzl et al., 2005).

abundance of endemic soils will be greater within than without the tension zone, and (iii) the distribution of endemic vascular plants will be related to that of endemic soils.

2. Methods and materials

The three hypotheses were tested using three approaches involving use of the USDA Natural Resources Conservation Service (NRCS) databases. To address soil richness, the number of soil orders, suborders, great groups, subgroups, families, series, phases, and map polygons was determined for each of Wisconsin's 72 counties using the NRCS "Geospatial Data Gateway" and county-scale data contained in SSURGO database (Soil Survey Staff, 2013a). Because the counties vary from 600 to 4000 km^2 in area, an area correction was applied.

The second approach focused on endemic soils in Wisconsin. The ranges of the 830 soil series listed in the Soil Series Classification Database for Wisconsin (Soil Survey Staff, 2013b) were examined. Three parameters were used to identify endemic soils in Wisconsin (Bockheim and Haus, 2013): (i) uniqueness to Wisconsin and immediately adjacent states; (ii) a centralized distribution and (iii) a lack of competing soil series. These parameters are analogous to those used by plant and animal ecologists (Anderson, 1994; Linder, 2001). The uniqueness of a soil to Wisconsin was determined from Geographic Extent maps of Official Soil Series Descriptions (Soil Survey Staff, 2013c) of the 830 soil series in the state. Soil series with a clustered distribution, regardless of total area, were considered to be those that occur in one or more adjacent counties.

Official Soil Series Descriptions were examined to assure that there were no competing soils, which are defined as soil series that are in the same family (United States Department of Agriculture Natural Resources Conservation Service, 2005, p. 614-3). This analysis presumes that the soil family is roughly equivalent to a plant or animal species (Bockheim and Haus, 2013). A spreadsheet of soil series considered as unique and endemic, with their areas and taxonomic level, was prepared. The series were then examined to see what soil properties appeared to contribute to their endemism.

The normalized numbers of soil taxa and endemic soils within and without the tension zone were compared using unstacked analysis of variance and Minitab software (Minitab Inc, 2013).

The third approach entailed comparing the county-wide frequency distributions of endemic soils to those of endemic vascular plants. To achieve this, we utilized the databases of the University of Wisconsin, Department of BotanyUniversity of Wisconsin (2013) and the Wisconsin Department of Natural Resources (2013). The latter database shows the distribution of endemic species on range maps. We determined the number of endemic vascular plants for each county and compared that to the number of soil series in each county using linear regression. Because of differences in scales of mapping endemic plants and soil series, we were not able to relate the occurrence of endemic plants to a specific soil series.

3. Results

3.1. Soil richness across the Wisconsin transition zone

Fig. 2 shows the number of soil taxa (uncorrected by area) for each county; the yellow, orange, and red patterns reflect progressively greater numbers of soil taxa. Whereas the 16 counties within the Wisconsin transitional zone contained greater normalized (area corrected) numbers of soil suborders, great groups, subgroups, families, series, and endemic soils, analysis of variance revealed that there was a significant difference only for soil suborders (Table 1). However, the Wisconsin transitional zone contains an unusually rich pedodiversity, including 6 of the 7 soil orders present in the state, 10 of 20 suborders, 17 of 50 great groups, and 28 of about 200 subgroups (Fig. 3).

All of the Spodosols (113 soil series) occur within or to the north of the transition zone (Table 2). Although 48% of the Alfisols occur within or to the north of the zone, 86% of the Hapludalfs, the dominant great group in Wisconsin, occur within or to the south of the transition zone. Eighty percent of the Mollisols occur within or to the south of this zone.

3.2. Endemic soils in Wisconsin

Of 830 soil series examined, 159 (19%) are judged as endemic to Wisconsin; 119 (75%) of the soil series occurred only in Wisconsin (the others also occurred in nearby Minnesota and Michigan). The endemic soil series account for 1.44 million ha, or 19% of Wisconsin's land area and occur in 7 orders, 14 suborders, 29 great groups, 83 subgroups, and 138 families (Table 3).

The mean area of endemic soil series is 11,280 ha, with a range of 45 to 106,160 ha and a median value of 4900 ha. The soil with the largest area is the Antigo series (Haplic Glossudalfs), which is Wisconsin's state soil, followed by the Gogebic (97,100 ha; Alfic Oxyaquic Fragiorthods), Champion (80,100 ha; Oxyaquic Fragiorthods), Wabeno (78,500 ha; Alfic Oxyaquic Fragiorthods), Valton (61,100 ha; Mollic Paleudalfs), and Cebana series (59,900 ha; Mollic Glossaqualfs) (Table 3).

There were no significant differences between the normalized numbers of endemic soils by county within the tension zone versus without the tension zone (Table 1). The largest proportion of the endemic soil series is either permanently or seasonally wet (37%), or features a glossic horizon (22%; Table 4). The glossic horizon (Gr. *glossa*, tongue) develops as a result of the degradation of clay-rich horizons from which clay and free iron oxides are removed (Soil Survey Staff, 2010). Other important features include the presence of bisequal profiles (9.4%), a lithic or paralithic contact (8.2%), and a lithologic discontinuity (without a bisequal profile) (7.5%). Bisequal soils form where two different sets of eluvial–illuvial processes are ongoing in the same soil. Lithic and paralithic contacts represent bedrock or other hard materials